World Academy of Science, Engineering and Technology
International Journal of Materials and Metallurgical Engineering
Vol:17, No:10, 2023

Simulation, Design, and 3D Print of Novel Highly Integrated TEG Device with Improved Thermal Energy Harvest Efficiency

Authors : Jaden Lu, Olivia Lu

Abstract : Despite the remarkable advancement of solar cell technology, the challenge of optimizing total solar energy harvest efficiency persists, primarily due to significant heat loss. This excess heat not only diminishes solar panel output efficiency but also curtails its operational lifespan. A promising approach to address this issue is the conversion of surplus heat into electricity. In recent years, there is growing interest in the use of thermoelectric generators (TEG) as a potential solution. The integration of efficient TEG devices holds the promise of augmenting overall energy harvest efficiency while prolonging the longevity of solar panels. While certain research groups have proposed the integration of solar cells and TEG devices, a substantial gap between conceptualization and practical implementation remains, largely attributed to low thermal energy conversion efficiency of TEG devices. To bridge this gap and meet the requisites of practical application, a feasible strategy involves the incorporation of a substantial number of p-n junctions within a confined unit volume. However, the manufacturing of high-density TEG p-n junctions presents a formidable challenge. The prevalent solution often leads to large device sizes to accommodate enough p-n junctions, consequently complicating integration with solar cells. Recently, the adoption of 3D printing technology has emerged as a promising solution to address this challenge by fabricating high-density p-n arrays. Despite this, further developmental efforts are necessary. Presently, the primary focus is on the 3D printing of vertically layered TEG devices, wherein p-n junction density remains constrained by spatial limitations and the constraints of 3D printing techniques. This study proposes a novel device configuration featuring horizontally arrayed p-n junctions of Bi2Te3. The structural design of the device is subjected to simulation through the Finite Element Method (FEM) within COMSOL Multiphysics software. Various device configurations are simulated to identify optimal device structure. Based on the simulation results, a new TEG device is fabricated utilizing 3D Selective laser melting (SLM) printing technology. Fusion 360 facilitates the translation of the COMSOL device structure into a 3D print file. The horizontal design offers a unique advantage, enabling the fabrication of densely packed, three-dimensional p-n junction arrays. The fabrication process entails printing a singular row of horizontal p-n junctions using the 3D SLM printing technique in a single layer. Subsequently, successive rows of p-n junction arrays are printed within the same layer, interconnected by thermally conductive copper. This sequence is replicated across multiple layers, separated by thermal insulating glass. This integration created in a highly compact three-dimensional TEG device with high density p-n junctions. The fabricated TEG device is then attached to the bottom of the solar cell using thermal glue. The whole device is characterized, with output data closely matching with COMSOL simulation results. Future research endeavors will encompass the refinement of thermoelectric materials. This includes the advancement of high-resolution 3D printing techniques tailored to diverse thermoelectric materials, along with the optimization of material microstructures such as porosity and doping. The objective is to achieve an optimal and highly integrated PV-TEG device that can substantially increase the solar energy harvest efficiency.

Keywords : thermoelectric, finite element method, 3d print, energy conversion
Conference Title : ICMSE 2023 : International Conference on Materials Science and Engineering
Conference Location : Los Angeles, United States
Conference Dates : October 30-31, 2023

Open Science Index, Materials and Metallurgical Engineering Vol:17, No:10, 2023 publications.waset.org/abstracts/173550.pdf